Strategic Plan

Strategy for National Earthquake Loss Reduction

National Earthquake Strategy Working Group

National Science and Technology Council

April 1996

The purpose of this report is to highlight ongoing Federal research efforts in this science and technology (S&T) field and to identify new and promising areas where there might be gaps in Federal support. The report is intended for internal planning purposes within the Federal agencies and as a mechanism to convey to the S&T community the types of research and research priorities being sponsored and considered by the Federal agencies. The Administration is committed to a broad range of high priority investments (including science and technology), as well as to deficit reduction, and to a smaller, more efficient Federal government. These commitments have created a very challenging budget environment -- requiring difficult decisions and a well thought-out strategy to ensure the best return for the nation's taxpayer. As part of this strategy, this document does not represent the final determinant in an overall Administration budget decision making process. The research programs presented in this report will have to compete for resources against many other high priority Federal programs. If these programs compete successfully, they will be reflected in future Administration budgets.

About the National Science and Technology Council

President Clinton established the National Science and Technology Council (NSTC) by Executive Order on November 23, 1993. This cabinet-level council is the principal means for the President to coordinate science, space, and technology policies across the Federal Government. The NSTC acts as a "virtual" agency for science and technology to coordinate the diverse parts of the Federal research and development enterprise. The NSTC is chaired by the President. Membership consists of the Vice President, Assistant to the President for Science and Technology, Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other top White House officials.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research, to improving transportation systems and strengthening fundamental research. The Council prepares research and development strategies that are coordinated across Federal agencies to form an investment package that is aimed at accomplishing multiple national goals.

To obtain additional information regarding the NSTC, please contact the NSTC Secretariat at 202-456-6100.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President on policy formulation and budget development on all questions in which science and technology are important elements; articulating the President's science and technology policies and programs; and fostering strong partnerships among Federal, State, and local governments, and the scientific communities in industry and the academe.

To obtain additional information regarding OSTP, please contact the OSTP Administrative Office at 202-395-7347.

THE WHITE HOUSE

WASHINGTON

April 16, 1996

Dear Colleague:

I am pleased to introduce the National Science and Technology Council (NSTC) report "Strategy for National Earthquake Loss Reduction." This document is the result of a thorough review of our Nation's earthquake policy by the National Earthquake Strategy Working Group with membership drawn from over a dozen Federal agencies in addition to the four National Earthquake Hazards Reduction Program (NEHRP) agencies. An important element of the review was a workshop which included representatives from State and local government and the private sector.

The strategy recommends a National Earthquake Loss Reduction Program (NEP) designed to strengthen and extend NEHRP. The NEP aims to: 1) focus scarce research and development dollars on the most effective means of saving lives and property and limiting social disruptions from earthquakes; 2) coordinate Federal mitigation R&D and emergency planning in a number of agencies beyond those in NEHRP to avoid duplication and ensure focus on priority goals; and 3) disseminate existing information to the user community and cooperate with the private sector and State and local jurisdications to apply effective mitigation strategies and measures. Leadership and coordination of the NEP will be conducted by the Federal Emergency Management Agency (FEMA).

The NEP should ensure that we remain the best in the world in our efforts to understand the earthquake threat and mitigate earthquake effects.

Sincerely,

John H. Gibbons
Assistant to the President
for
Science and Technology

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STRATEGY FOR NATIONAL EARTHQUAKE LOSS REDUCTION

Strategy for National Earthquake Loss Reduction

Although earthquakes are inevitable natural hazards, they need not be inevitable disasters. Through prudent actions our nation can reduce losses of life, casualties, property losses, and social and economic disruptions from future earthquakes.

A SEVERE NATIONAL THREAT

It is likely that one or more severely damaging earthquakes, which equal or exceed the 1994 Northridge earthquake in magnitude, will strike the United States within the next decade. Repeats of the 1906 San Francisco and the 1964 Alaska earthquakes loom somewhere in the future for California and Alaska. Although most people associate them with the nation's West Coast, earthquakes pose a significant risk in at least 39 states. The New Madrid, Missouri, earthquake of 1811 was as powerful as the 1906 San Francisco earthquake and was felt across the entire eastern United States. The National Research Council has estimated that a repeat of the 1811 New Madrid earthquake could result in hundreds to thousands of lives lost and over $100 billion dollars of damage in a 26-state area. In areas such as the Midwest that experience earthquakes infrequently, the earthquake hazard awareness, vulnerability, and risk sensitivity of the residents is low. Even in areas that have frequent earthquakes, preparedness is often highly variable.

Earthquakes release the strain built up in the earth's crust by the ongoing action of geologic deformation. Potentially damaging earthquakes are caused by sudden movements along faults. Earthquakes may result in offsets of up to thirty feet which extend up to hundreds of miles along the length of the faults. The 1906 San Francisco earthquake and the 1964 Alaska earthquake were of this scale. Lesser earthquakes, like the 1971 San Fernando earthquake, the 1989 Loma Prieta earthquake are intermediate in magnitude but were still felt over thousands of square miles. Even in relatively well-studied areas surprises can occur. The 1994 Northridge earthquake, which occurred along an unrecognized, buried fault, is a prime example. In the Central and Eastern United States, where earthquakes are less frequent than in the West, there are potentially more surprises; because the risk is less well understood, mitigation practices are less commonly implemented and the potential for damage, should an earthquake occur, is much greater.

Earthquake effects include violent ground shaking and earthquake-induced ground failure such as liquefaction (the sudden conversion of soil to a liquid mass due to shaking as occurred in the 1995 Kobe earthquake), landslide, or ground surface rupture. Submarine earthquakes can induce damaging tsunami (seismic sea waves or "tidal" waves), which can travel undiminished thousands of miles before bringing destruction to coastal areas. Earthquakes may also cause permanent changes in sea-level elevation through local ground subsidence or uplift.

The principal threat from earthquakes is shaking damage and the collapse of buildings and other structures that have been inadequately designed or constructed to resist seismic forces. Major earthquakes can severely interrupt regional or national economic activity by damaging lifelines such as roads, railways, water, power, and communication lines. Seismic damage interrupts the flow to users of vital resources and services, thereby increasing the risk to life safety and impeding economic growth. Ground failure hazards such as subsidence, landslides, liquefaction, and settlement also cause damage to structures and lifelines, and are a major threat to dams, waterfront structures, highway facilities, and buried lifelines.

Although much remains to be learned about the most effective and economical techniques for enhancing the seismic safety of structures, many proven cost-effective measures are already being

applied in the United States. Considering that little to no strong earthquake ground motion data was collected prior to the 1933 Long Beach earthquake, there have been great accomplishments in the design and construction of earthquake-resistant structures. Because of improved building codes, land use planning, and preparedness, the losses in the San Francisco Bay area from the 1989 Loma Prieta earthquake and in the Los Angeles area from the 1994 Northridge earthquake were much lower than would have occurred in a less well-prepared region[1].

The current legal requirements for constructing buildings, highways, bridges, and other lifelines in earthquake-prone regions vary greatly from one region to another, or even from one local jurisdiction to another, despite the fact that seismic safety can often be incorporated in new buildings and lifelines at little or no extra cost for design, construction, or operation. Local action to provide earthquake mitigation measures depends largely upon the awareness and education of public officials, engineers, planners, the business community, and the general populace.

While the United States has lost comparatively few lives in earthquakes in recent years, the number can be reduced further. The cost of earthquake damage is still unacceptably high. All regions that are prone to earthquakes must begin to undertake mitigation measures to reduce future human and property losses. While earthquakes are inevitable natural hazards, they need not be inevitable disasters. Our nation can reduce losses of life, casualties, property losses, and social and economic disruptions from future earthquakes through prudent actions.

CURRENT EARTHQUAKE PROGRAM

In 1977 Congress passed the Earthquake Hazards Reduction Act establishing the National Earthquake Hazards Reduction Program (NEHRP) as a long term, nationwide, earthquake risk reduction program. The Act was amended and reauthorized in 1990. Member agencies in the program are the United States Geological Survey (USGS), the National Science Foundation (NSF), the Federal Emergency Management Agency (FEMA), and the National Institute of Standards and Technology (NIST). The purpose of NEHRP has been to reduce the risks to life and property in the United States from earthquakes through the establishment and maintenance of an effective national earthquake risk reduction program. The Act's aims include improved understanding, characterization, and prediction of hazards and vulnerabilities; improved model building codes and land use practices; reduced risks of earthquakes through post-earthquake investigations and education; development and improvement of design and construction techniques; improved mitigation capacity; and accelerated application of research results. While the aims of NEHRP were broad, the agencies that sought funds under the 1977 Act were the ones largely engaged in research and development.

The NEHRP agencies, working both individually and in cooperative alliances with each other, other federal and state agencies, private companies, universities, and regional, voluntary, and professional organizations, have made significant gains in our understanding and characterization of earthquake hazards, our preparation for earthquakes, and how to mitigate the damage they cause (Appendix A1). However, much remains to be learned about the most effective and economical techniques for enhancing the seismic safety of the built environment. Moreover, implementation of what we have learned significantly lags the state our knowledge.

NEED FOR CHANGE

Funding for NEHRP has focused on research to increase knowledge about earthquake hazards and on engineering techniques to reduce earthquake losses. The mitigation practices developed through research and development must be voluntarily adopted by bodies largely outside the control of the

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[1] See Practical Lessons from the Loma Prieta Earthquake, published by the National Research Council, and the California Governor's Commission Report "Competing Against Time."

federal government. As a consequence, the degree of national earthquake risk reduction envisioned by many has not been achieved (Appendix A2). There needs to be additional education of people about the risk of earthquake hazards in their region and the employment of steps which can be taken to mitigate these hazards.

NEHRP's research and development programs demonstrate that the cost of seismic safety for protection of life rarely exceeds two percent of the construction cost for well-designed new buildings. However, new construction changes the entire American building inventory by as little as one percent each year. This means that new construction reduces the potential number of casualties, damaged buildings, and corresponding social/economic disruptions caused by earthquakes by only a very small percentage each year. Furthermore, the normal time required to research a new idea, move it through code acceptance, and into widespread practice can be more than a decade. Thus even over several decades, earthquake loss reduction will be modest in much of the United States despite any great breakthroughs which have or may occur in science and engineering--unless greater attention is given to improving the performance of existing buildings and lifelines.

The initial NEHRP legislation envisioned the federal role as that of a provider of information. Subsequent amendments to the legislation added the roles of stimulating and promoting risk reduction actions. However, the actual level of such actions as evidenced by the adoption of earthquake resistant building codes by local or state governments has not kept pace with expectations. This gap between risk reduction action to date and expectations has led to the recommendation from the Advisory Committee of the National Earthquake Hazard Reduction Program that NEHRP "incorporate a programmatic implementation mechanism that creates strong incentives for the adoption of earthquake risk reduction measures..." These issues are complex and require extensive analysis to ensure that policies have the intended consequences; their resolution will likely require legislation. Some of these issues are currently being addressed by a working group led by the National Economic Council. Others would be addressed by the Program Office envisioned in the new National Earthquake loss reduction Program (NEP).

Besides the four agencies designated by the National Earthquake Reduction Act, a number of other agencies also have a fundamental interest in, and have significantly investigated, earthquake risk reduction. The Department of Veterans Affairs, Department of Defense (Army Corps of Engineers and Navy), Department of Energy, Department of Transportation (Federal Highway Administration), Department of Health and Human Services, Department of Housing and Urban Development, and Nuclear Regulatory Commission all engage in substantial independent hazard identification and risk reduction programs for their mission-oriented programs, and the National Aeronautics and Space Administration (NASA) is active in earthquake process research as part of its Mission to Planet Earth. The earthquake-related activities of these non-NEHRP agencies have in the past lacked an integrating mechanism.

In November 1993 the Chairman of the House of Representatives Committee on Science, Space and Technology and a bipartisan group of eight other Representatives signed a letter to the President outlining continuing concern about the Federal government's efforts to reduce the nation's earthquake losses. Their main concerns focused on NEHRP and were basically threefold: 1) a lack of strategic planning; 2) insufficient coordination and implementation of research results; 3) and a lack of emphasis on mitigation. The January 1994 Northridge Earthquake gave a greater sense of urgency and importance to the issue.

To address the need to make NEHRP and our nation's earthquake research effort more effective, Dr. John H. Gibbons, Presidential Science Advisor and Director of the Office of Science and Technology Policy (OSTP), directed in March 1994 that a study under the auspices of the Office of Science and Technology Policy (OSTP) be undertaken to review the research and implementation issues related to earthquake hazards. The review examined the performance and effectiveness of

the national earthquake program from two perspectives: 1) earthquake research and development (R&D) performed under the sponsorship of the NEHRP, and 2) the implementation of knowledge gained from this R&D in reducing earthquake losses. The review was conducted under the direction of the President's National Science and Technology Council (NSTC) and was coordinated with the Subcommittee on Natural Disaster Reduction.

The review activities were conducted by the National Earthquake Strategy Working Group (NESW), with membership drawn from over a dozen federal agencies in addition to the four NEHRP agencies, and was sponsored and chaired by OSTP (participation listed in Appendix B1). An important element of the review was a National Earthquake Strategy Workshop convened by OSTP and held in Washington, D.C., June 6-8, 1994. The workshop included representatives from each of the NESW agencies and a full spectrum of the user community, from architects, earth scientists, earthquake engineers, emergency managers to social scientists, building officials, and facility owners (listed in Appendix B2). The workshop was used to identify the user community's views on priorities and goals for a National Earthquake Loss Reduction Strategy, the level of effort required to meet these goals, and the necessary federal coordination mechanisms.

A NEW NATIONAL EARTHQUAKE STRATEGY

The NESW's review has resulted in the formulation of a strategy that will enhance existing elements of NEHRP and mobilize and coordinate the actions of numerous programs in the federal government into an aggressive, focused National Earthquake loss reduction Program (NEP).

The NEP will enhance cooperation and coordination among the NEHRP agencies and will include numerous other federal agencies involved in earthquake-related activities to avoid duplication and ensure focus on priority goals. The program will ensure inter-agency strategic planning so that our financial resources are directed to the most effective means for savings lives and property and limiting the social and economic disruptions from earthquakes. The NEP will strive to improve the linkages in earthquake loss prevention and mitigation between the federal government and the State and local governments and private sectors where much of the mitigation measures must be undertaken. One of the most important elements of the NEP is education - informing and educating people of the regional hazard and of steps that could be taken to mitigate the hazard.

The NESW also recognized that a major reason for the difficulty in identifying priorities and in evaluating the success of NEHRP has been a lack of specified goals, targets, and priorities against which expectations can be set and performance measured. An important feature of this national Strategy is the establishment and articulation of goals in nine major categories, each supported by specific targets, products, and proposed timelines that provide a framework for measuring progress and mapping a path forward. Existing federal programs will be streamlined and tailored to attain these goals; no new funding is expected.

The goals of the National Earthquake Loss Reduction Program are:

- Provide leadership and coordination for federal earthquake research;
- Improve technology transfer and outreach;
- Improve engineering of the built environment;
- Improve data for construction standards and codes;
- Continue the development of seismic hazards and risk assessment tools;
- Analyze seismic hazard mitigation incentives;
- Develop understanding of societal impacts and responses related to earthquake hazard mitigation;
- Analyze the medical and public health consequences of earthquakes; and
- Continue documentation of earthquakes and their effects.

The NEP will also examine wind effects and their mitigation as part of its charter. The expansion is appropriate because the forces from severe storms and ground-shaking have similarly destructive effects on the built environment and because mitigation efforts and improved building standards and practices will be most usefully and efficiently implemented if developed for both earthquake and wind hazards.

TARGETS AND RESPONSIBILITIES

To accomplish the goals of the NEP, the NESW developed a series of targets, together with agency responsibility. These specific actions will be the measure of the NEP's success. An expanded description of these targets is contained in Appendix C. Assignment of agency responsibility is made in accordance with Public Law 95-124, as amended, or, where targets fall outside the scope of Public Law 95-124, to the federal agency whose current programmatic activities best align with the target. In most cases the conduct of the research and outreach required to achieve these targets and produce the corresponding products involves the coordinated efforts of several agencies and requires working partnerships with State and local officials, volunteer professional groups, and other interested parties.

1. Provide leadership and coordination for federal earthquake research:
The objectives are to integrate federal earthquake-related program and budget planning; develop a balanced, prioritized and integrated national research and implementation agenda; facilitate cooperation and information exchange among all interested parties, domestic and international; advocate policies and practices and recommend legislation as appropriate; and conduct periodic performance assessments. Responsibility for meeting this goal lies with all program agencies as well as with the interagency Program Office to be established as part of the NEP.

Targets	Responsibility	Other
1. Work with the National Science and Technology Council to establish a leadership mechanism to assure implementation of the Strategy. The mechanism shall report every two years to the President and to the Congress.	All Program Agencies	
2. Integrate federal earthquake-related planning into the new mechanism over a five year period beginning in Fiscal Year 1996.	All Program Agencies	
3. Develop a balanced national prioritized research and mitigation agenda, confirmed or adjusted on a regular basis, incorporating a broad-based assessment of user needs that includes the needs of agencies to support special or unique missions.	All Program Agencies	
4. Facilitate cooperation and leverage across all agencies and groups with programmatic interests in earthquake loss reduction, including, but not limited to federal, state, local, private, voluntary, and public utility groups.	All Program Agencies	
5. Develop an overall nationwide strategic plan to integrate and coordinate existing but currently separate research and mitigation programs into a unified, needs-driven, goal-oriented program consistent with the National Earthquake Strategy goals.	All Program Agencies	
6. Advocate policies and practices nationwide and recommend legislation as appropriate.	All Program Agencies	
7. Conduct a biennial performance assessment and report of coordination and mitigation activities under the Program. This report shall include accomplishments towards achieving the goals and recommendations for improving the Strategy.	All Program Agencies	
8. Provide a focal point for federal international collaborative programs in research on earthquake loss reduction and in technology transfer for improved earthquake hazard mitigation.	All Program Agencies	

2. Continue and expand technology transfer and outreach

Developing and sustaining an awareness of risk and risk reduction techniques and technology is a continuing challenge. The Strategy includes development of credible earthquake planning scenarios; assessment of the costs and benefits of alternative mitigation strategies for new and existing construction; targeted training programs and development and dissemination of tools for design professionals; support of public and private consortia with interests in this area; making research more effectively available to insurance regulators and the insurance industry; and a more systematic approach to communicating the nation's achievements in earthquake hazard reduction.

Targets	Responsibility	Other
1. Develop credible earthquake scenarios including vulnerabilities and loss estimates which are sensitive to emotional and political issues, using GIS technology.	FEMA USGS NSF	NIST, HHS, NCS, DVA, NOAA
2. Develop assessments of the costs and benefits of various mitigation strategies for new and existing construction.	All Program Agencies	
3. Conduct targeted training and education programs.	All Program Agencies	
4. Encourage and assist regional consortia.	All Program Agencies	
5. Embrace and support voluntary mitigation.	All Program Agencies	
6. Communicate achievements, progress, and successes of the National Earthquake loss reduction Program and its member agencies and alliances.	All Program Agencies	
7. Encourage and assist insurance regulators and the insurance industry through publishing regular reports and presenting updates in information and methodology at insurance fora.	FEMA NIST Treasury	HHS, USGS, HUD, NSF, DOE, DVA, DOT
8. Develop and disseminate tools for design professionals that incorporate state-of-the-art information on mitigation strategies and methods.	NIST NSF USGS	

3. Improve engineering of the built environment:

While in recent times the United States has built an enviable record in terms of the comparatively small number of lives lost in earthquakes, the cost of damage to buildings and infrastructure is still unacceptably high. Future research will continue to develop concepts and criteria to permit the continued functioning of buildings and lifelines after an earthquake and develop effective and economical methods for evaluating and retrofitting existing seismically hazardous structures. Work will also examine wind effects, which have similarly destructive effects on the built environment, to improve building standards and practices.

Targets	Responsibility	Other
1. Develop improved analytical techniques for dynamic, non-linear response of complex, unconventional materials, structures, and lifelines.	NIST NSF	FEMA, DOE, DOD, USGS, HUD, EPA, DOT
2. Develop new and innovative systems of construction that are economical yet inherently earthquake resistant.	NIST NSF	FEMA, DOE, DOD, HUD, DOT
3. Develop performance-based design concepts and criteria for buildings and lifeline systems.	NIST NSF	FEMA, DOE, DOD, HUD, DOT
4. Understand seismic behavior of non-building structures and lifeline systems.	NIST NSF	FEMA, DOE, DOD, HUD, USGS, DOT
5. Develop effective and economical methods to evaluate and retrofit existing seismically hazardous structures.	NSF, NIST	FEMA, DOE, DOD, HUD, DOT
6. Develop experimental engineering research capability and conduct verification and proof-of-principle projects.	NSF, NIST	FEMA, DOE, DOD, HUD, DOT

4 Improve data for construction standards and codes

Efforts will focus on developing and making available to code-writing bodies materials to improve standards for construction of new buildings and lifelines, and rehabilitation standards for rehabilitating existing buildings and other structures. Concurrently, efforts will be undertaken to develop multihazard (wind, earthquake, tsunami) standards and to develop improved capabilities for the analysis and testing of structures and lifelines.

Targets	Responsibility	Other
1. Develop and make available resource documents for use by code writing bodies, state insurance offices, and insurance firms on improved functionality-preserving seismic design criteria for new buildings and other structures, including cost estimates.	NIST NSF FEMA	DOE, DOD, EPA, DOT, DVA, USGS, NCS, HUD, HHS, OMB, EPA
2. Develop and make available resource documents for use by code writing bodies, insurance companies, and regulators on performance-based seismic design standards for lifelines.	NIST NSF FEMA	USGS, DOE, NCS, DOD, EPA, DOT, HHS, DVA, HUD
3. By the year 2005, develop and make available resource documents for use by code writing bodies, insurance companies, and regulators on rehabilitation standards for existing buildings.	FEMA NIST NSF	FEMA, DOD, EPA, DOT, GSA, HHS, DVA, DOE, HUD
4. By the year 2000, introduce multi-hazard standards.	FEMA NIST NSF	USGS, FEMA, DOD, EPA, DOT, GSA, DVA, HUD, DOE
5. Develop improved capabilities for analysis and testing of structures, including lifelines.	NSF, NIST	FEMA, DOD, DOE, DOT, HUD, DVA, USGS
6. Develop means to mitigate tsunami effects by incorporating readings from deep-water pressure sensors to improve early tsunami warning systems.	NOAA USGS	FEMA, NIST, NSF, USGS, DOT, HHS, DOD, DVA

5: Continue development of seismic hazard and risk assessment tools:

There is an urgent need to develop and provide immediately useful information to planners and decision makers. Research will develop improved methods for estimating losses from potential earthquakes and quantifying the risk for high-hazard communities. This effort will produce large- and small-scale maps that depict the seismic hazards, accessible through geographic information system data bases. Work will continue to improve understanding of basic seismic forces, improve the quality and quantity of data recorded in actual events, and advance forecasting techniques and technologies for both earthquakes and resulting tsunamis.

Targets	Responsibility	Other
1. Improve loss estimation methodology. Develop earthquake scenarios linking building types and lifelines with the effects of strong shaking and ground failure to provide better estimates of life losses, injure, public health impact, property losses, and indirect economic effects.	USGS	NIST, GSA, DOT, DOD, DOE, NSF, FEMA, HHS, HUD
2. By the year 1998, develop seismic risk assessment methodology and quantify seismic risk for communities exposed to high seismic hazard	USGS	FEMA, NSF, DOE, NOAA, DVA, HUD
3. By the year 2000, provide demonstration seismic hazard microzonation maps for representative sections of selected cities exposed to the highest earthquake hazard	USGS	FEMA, NSF, DOE, NOAA, NASA, DVA
4. By the year 2005 provide regional seismic hazard maps, interpretations, and guidelines as the basis for seismic zonation, implementation of earthquake codes, and local land-use decisions	USGS	FEMA, NSF, DOE, NASA, NOAA, DVA
5. Improve earthquake hazard assessment and forecasting using historical seismicity and paleoseismicity, and evaluate the role of emerging technologies	USGS NASA	NSF, DOE
6. Provide high-quality earthquake recordings and derived basic seismic information to researchers and practitioners on an ongoing basis.	USGS	NSF, DOE, NASA, NOAA, DOD
7. Understand critical earthquake topics such as plate interaction in subduction zones, blind faults [illegible] and thrust belts appropriate to geographically diverse areas.	USGS	NASA, NSF, DOE
8. Improve understanding of strong ground motions, including nonlinear site response, directivity and topographic effects, and foundation instability.	USGS NSF	NIST, DOE, DOD, DOT, DVA
9. Develop an accessible digital GIS database.	USGS FEMA	FEMA, NSF, EPA, DOT, NASA, DOD, NOAA, DVA
10. Improve foreknowledge of and response to tsunami hazards	NOAA USGS FEMA	NIST, NSF, USGS, DOT, HHS, DVA, DOD

6. Analyze seismic hazard mitigation incentives

Activities in this category will explore and evaluate mechanisms that may encourage the adoption and enforcement of up-to-date model codes and standards, as well as explore socioeconomic factors that impede mitigation and preparedness.

Targets	Responsibility	Other
1. Evaluate mechanisms and advise Congress and relevant Executive Branch offices to achieve adoption and enforcement by the year 2000 of up-to-date model building codes and standards to govern all new building and lifeline design and construction.	FEMA	NIST, GSA, OMB, NEC, DOD, DOE, HUD
2. Provide guidance and lead by example on specific mitigation measures which may be used in a federal incentive program.	FEMA NIST USGS	GSA, EPA, HHS, OMB, NEC, NSF, HUD
3. Better understand the socioeconomic barriers to mitigation and preparedness.	FEMA	OMB, NEC, HUD

7. Develop understanding of the societal and institutional issues related to earthquake hazard mitigation

Since hazard reduction measures are ultimately local actions, the NEP focuses on social factors, including those that facilitate or hinder the adoption of seismic safety measures; social and economic costs and benefits of these measures; social responses to earthquakes; and the practice and techniques of multihazard mitigation and preparedness planning.

Targets	Responsibility	Other
1. Determine the social and economic benefits and costs of various mitigation measures such as codes, land-use planning, insurance, and educational programs for different sectors of society.	FEMA NSF USGS	HUD, Treasury
2. Identify the social, economic, and political factors that facilitate and hinder the adoption and implementation of seismic safety measures.	FEMA NSF USGS	HUD
3. Investigate the societal responses to earthquakes, including emergency response systems, and individual, business, and community recovery from such events.	FEMA NSF	HUD, HHS, USGS
4. Analyze multi-hazard mitigation and preparedness planning.	FEMA NSF	HUD, HHS, USGS

8. Analyze the medical and public health consequences of earthquakes

Work in this area will include support of epidemiological research, the integration of casualty and medical needs predictions into loss estimation models, improvement in the rapid assessment of earthquake health effects - both short and long term, and associated development of more effective rescue, medical training, and public health programs.

Targets	Responsibility	Other
1. Identify potential strategies to prevent or mitigate the adverse health consequences of earthquakes through epidemiological research	HHS	FEMA, NOAA, DVA
2. Integrate predictions of casualties and medical needs into methodologies for estimating earthquake loss	HHS, NSF USGS FEMA	NOAA, DVA, NCS, NSF, NIST
3. Develop validated indicators for rapid assessment of the health effects and potential health effects of earthquakes and related health needs in order to determine the most appropriate medical requirements during the critical first few hours after impact	HHS	FEMA, NIST, EPA, DVA, DOE, DOD
4. Develop more effective rescue, medical training, and public health programs.	HHS FEMA	NIST, DOD, DOT, GSA, DVA
5. Develop effective operational procedures for meeting the health needs of people with special requirements such as evacuees from hospitals and nursing homes	HHS FEMA	NIST, NSF, DOD, EPA, DOT, GSA, NASA, NCS, NOAA, OMB, DVA, DOE, HUD
6. Develop an emergency communications system to ensure effective coordination of medical and health needs at the local, State, and Federal levels	FEMA	NIST, NSF, DOD, EPA, DOT, GSA, HHS, NASA, NCS, NOAA, OMB, DVA, DOE, HUD, HHS

9. Continue documentation of earthquakes and their effects

Efforts will focus on standards and specifications for official documentation of earthquakes, the establishment of timelines for the publication of reports, and the conventions for distributing this information.

Targets	Responsibility	Other
1. Establish standards and specifications for official documentation of earthquakes by 1996.	FEMA USGS	NIST, NSF, DOD, EPA, DOT, GSA, HHS, NASA, NCS, NOAA, OMB, DVA, DOE, HUD, HHS
2. Prepare and publish a reconnaissance report, collect ephemeral data, and complete major aspects of a research plan within one year of each major earthquake event.	FEMA USGS	NIST, NSF, DOD, EPA, DOT, GSA, HHS, NASA, NCS, NOAA, OMB, DVA, DOE, HUD, HHS
3. Prepare and publish an in-depth report within four years of each major earthquake event.	FEMA USGS	NIST, NSF, DOD, EPA, DOT, GSA, HHS, NASA, NCS, NOAA, OMB, DVA, DOE, HUD, HHS
4. Post information on electronic data base for easy access by any interested party.	FEMA USGS	NIST, NSF, DOD, EPA, DOT, GSA, HHS, NASA, NCS, NOAA, OMB, DVA, DOE, HUD, HHS

UTILIZATION OF NEW TECHNOLOGIES

The NEP embraces testing the usefulness of promising new technologies for understanding earthquakes and reducing earthquake-caused loss that have emerged since the original formation of NEHRP. Space-based technologies such as Global Positioning System (GPS) technology can be utilized to provide continuous-in-time measurements of how the ground is deforming in areas of earthquake risk, and Synthetic Aperture Radar remote sensing applications are being developed to provide a spatially continuous image of crustal deformation. Other new geophysical methods include high-performance seismometers and seismographs for recording broadband, high-dynamic-range ground motion which are being installed world-wide. These stations are particularly important for emergency response to damaging earthquakes and for recording the strong motion data needed for building design. Borehole tiltmeters, borehole strainmeters, and laser-ranging instrumentation measure ongoing distortion of the earth's crust and may eventually aid earthquake prediction. Paleoseismic methods have rapidly advanced in the last decade and enable identification of pre-historic earthquakes and improved estimates of earthquake recurrence intervals. Probabilistic seismic hazard methods have been developed to provide estimates of earthquake ground motion in areas of low recurrence (such as the eastern U.S.). New Geographic Information System (GIS) technology will be used to integrate the information from these and a variety of other data sets.

New technologies in the area of earthquake engineering include advanced modeling and simulation of the dynamic, non-linear response of constructed facilities to earthquake effects, use of energy absorption systems, and passive and active control systems for reduction of structural response to ground shaking with resulting reduction in damage and interruption of functions, and innovative structural materials and systems such as high-performance composites for strengthening existing structures:

- Advanced non-destructive evaluation methods such as ultrasonic, acoustic emission, infrared thermography techniques have been developed to monitor and assess structures and detect flaws which could make them more susceptible to ground shaking.
- Optic-fiber sensors and innovative embedment techniques have proven to be extremely effective in sensing the dynamic response of structures under seismic conditions.
- Neural networks and fuzzy logic-based mathematics techniques are very useful in identifying the properties and damage potential of large, complex structures.
- Hydraulic, electromagnetic-based actuators, or their hybrids, are being developed to produce the required control forces to counter-balance impeding earthquake loads.
- High-performance materials, including high-strength, highly ductile and weldable steel and alloys and cement-based materials which can be made super strong, tough, and durable--properties of importance to earthquake resistance--are becoming common for construction of critical buildings and infrastructures in seismic zones.

IMPLEMENTATION

The NEP will be led and coordinated by FEMA which will be responsible for the management, planning, reporting, and budgetary coordination of the Program through interaction with an interagency group composed of representatives of those agencies with programmatic interests in earthquake research and mitigation. FEMA will serve as a single point of contact within the federal government for information related to earthquake research and mitigation and will help to plan and direct workshops and other outreach activities aimed at transferring research results to state and local governments and the private sector[1]. FEMA, together with the interagency group, will work with agencies conducting earthquake research and mitigation to formulate research priorities and

[1] FEMA is the lead NEHRP agency and serves as the lead agency for implementation of Executive Orders 12699 and 12941 (Appendix D) dealing with seismic safety of new and existing federally owned and leased buildings.

provide these priorities to federal agencies for program formulation and ensure that unnecessarily duplicative research does not take place.

Participation in the NEP will be open to all agencies with activities that include earthquake research or loss mitigation. The NEP's membership will reflect the evolution of federal agencies' programmatic interests and capabilities since the formation of NEHRP in 1977. The scale of an agency's contribution to reducing the nation's earthquake losses may not be fully apparent until after a detailed budget and programmatic analysis has been undertaken.

Specific activities of the interagency group through FEMA will be to:

- Advocate Program policies and practices;
- Coordinate interagency strategic planning;
- Recommend Program priorities that do not conflict with agency activities conducted in support of special or unique missions;
- Compile the member agencies' annual accounting for earthquake-related Program funds;
- Encourage and offer guidance to non-federal organizations and consortia in efforts to reduce earthquake losses;
- Conduct periodic national forums and develop additional means to include the views, interests, and priorities of non-federal communities in the Program; and
- Evaluate and report every two years upon Program performance and effectiveness to the President and the Congress.

The interagency group will be led by a full-time Program Director who will report to an Associate Director of FEMA. Several co-located, full to part-time associated officers detailed from other agencies with major earthquake research programs may aid the Program Director.

The Subcommittee on Natural Disaster Reduction (SNDR) of the Committee on Environment and Natural Resources (CENR), a committee within the National Science and Technology Council, will review the NEP on an ongoing basis, and communicate findings to the National Science and Technology Council.

Federal funding for the NEP is presumed to include those funds currently expended on earthquake issues by the NEHRP member agencies (United States Geological Survey [USGS], National Science Foundation [NSF], Federal Emergency Management Agency [FEMA], and National Institute of Standards and Technology [NIST]) as well as other Federal agencies involved in earthquake research or loss mitigation technology development or implementation. Individual activities such as workshops or publications will be paid for directly by the sponsoring agencies. This report does not imply or intend redirecting budgetary authority between agencies, or propose actions that would impact agency activities conducted in support of special or unique missions. The non-Federal implementation of earthquake loss mitigation practices is not a direct fiscal responsibility of the program. Most cost decisions must be made at the State or local levels of government or by the private sector. Mitigation implementation is a long term investment which occurs over time periods of tens of years and is applied on an incremental basis. Success of the NEP will depend in large part on stimulating the actions of these groups to mitigate earthquake hazards.

THE NEP AND NATIONAL GOALS

The NEP responds to the guidelines issued by the Administration's Office of Management and Budget and Office of Science and Technology Policy, which call for closer linkages between scientific research and broad national goals. Basic research dealing with the scientific, engineering, and socioeconomic aspects of earthquakes is a fundamental part of the national strategy. Basic research provides a close link to the training of the next generation of scientists, engineers, and practitioners responsible for the national program in the future. The NEP also

responds to the Administration's science and technology management principle that industry play a partnership role in establishing priorities for federal programs.

INTERNATIONAL COLLABORATION

To achieve earthquake loss reduction internationally is important to the United States for several reasons. Collaboration on research leverages scarce funds and allows access to a wider array of research results including those derived from earthquakes which occur outside of our nation. Stimulation of increased earthquake mitigation internationally will help reduce loss of life and property and can help conserve funds dedicated to international disaster assistance. NEHRP has helped to make the United States a leader in earthquake assessment and mitigation technologies. Increased attention to these activities by foreign countries provides U.S. companies with enhanced market opportunities.

The NEP gains substantially from international collaboration on earthquake effects, mitigation practices, and implementation strategies. It also gains from professional and commercial associations throughout the world which develop, publicize, and implement earthquake risk reduction practices. NEHRP and most participating non-NEHRP agencies participate in bi- or multi-lateral science and technology programs. Examples of such collaboration are the U.S.-Japan Cooperative Program in Natural Resources (UJNR) Panel on Winds and Seismic Effects, the U.S.-People's Republic of China program on seismic hazards and earthquake studies, the U.S.-Russia program on earthquake disaster reduction, the U.S.-Japan Science and Technology Working Group and its subcommittee on Satellite Applications, and the U.S. participation in the International Decade for Natural Disaster Reduction (IDNDR). The UJNR Panel on Wind and Seismic Effects, which began 27 years ago, allows researchers and practitioners of both countries to exchange specific technical data and personnel, and to collaborate on experimental work including large-scale testing. Sixteen U.S. federal agencies, including the NEHRP agencies, and six Japanese government agencies participate in the panel activities.

In the area of research on crustal strain and earthquake processes, the Global Digital Seismograph Network (IRIS, NSF, and USGS) collects data from, and distributes information to, Europe, Latin America, and Asia. NSF is a major supporter of the International Seismic Centre, the world's main collector and publisher of earthquake data. The United States cooperates with countries throughout the world to improve global seismic monitoring and to understand earthquake hazards in seismically active regions of Latin America, Asia, and Southern Europe. Scientific protocols have been renewed with several members of the Commonwealth of Independent States (former Soviet Union) and the People's Republic of China to maintain a vigorous exchange of seismic monitoring data. The Global Geodetic Network (NASA, NOAA, and NSF) uses high-resolution, space-based geodetic techniques, with permanent measurement sites on all continents, to monitor global crustal motion and deformation, exchanging data and coordinating observations through agreements with some 45 countries.

Transferring technology and providing training and expertise to earthquake-prone developing countries so that they can implement hazard mitigation practices is much cheaper than providing disaster relief after a devastating earthquake. The U.S. Geological Survey, in cooperation with United Nations Educational, Scientific, and Cultural Organization and the U.S. State Department, currently provides training and expertise on a reimbursable basis to improve earthquake hazard reduction in South America, Southern Europe, North Africa, the Eastern Mediterranean region, and Southeast Asia. Additionally, in cooperation with the U.S. Office of Foreign Disaster Assistance of the Agency for International Development, the USGS provides technical assistance in South and Central America and Asia to develop a more uniform basis to assess earthquake risk. The program is achieving hazard reduction by developing a wide variety of information and data exchange programs.

APPENDIX A. National Earthquake Hazards Reduction Program (NEHRP)

Appendix A1. NEHRP History and Accomplishments

In 1977, Congress passed the Earthquake Hazards Reduction Act (the Act) which established the National Earthquake Hazard Reduction Program (NEHRP) - a long-term, earthquake risk reduction program. Member agencies in the program are the United States Geological Survey (USGS), the National Science Foundation (NSF), the Federal Emergency Management Agency (FEMA), and the National Institute of Standards and Technology (NIST). The agencies included under the 1977 act were mainly those engaged in research and development.

The program brought together concerns and recommendations that had been developing along both legislative and executive tracks: a Congressional track beginning with the devastating 1964 Alaska earthquake and fueled by the 1971 San Fernando earthquake, and an executive track which began during the Ford administration when Vice President Rockefeller formed a commission to identify new technological opportunities for earthquake mitigation. In parallel during the mid-1970's, concern over the implications of the then recently identified Palmdale bulge in southern California led to the formation of the Newmark-Stever Committee by the President's Office of Science and Technology Policy (OSTP). The Newmark-Stever Committee was tasked with developing a program to understand and address the seismic hazard in southern California. However, the scope of the program was subsequently broadened to include national earthquake hazards. During the Carter administration, the Federal Emergency Management Agency (FEMA) was formed. FEMA was recommended by OSTP to coordinate the work of Federal agencies in the program recommended by the Newmark-Stever Committee. Little new funding was to be provided in the recommended program; the intent was for the individual member agencies to seek funding from within their own budget allocation. The National Earthquake Hazard Reduction Act implemented many of the Newmark-Stever Committee recommendations, including designating member agencies, their activities and areas of responsibility, and the funds identified by those agencies as part of NEHRP.

The purpose of NEHRP is to reduce the risks to life and property in the United States from earthquakes through the establishment and maintenance of an effective national earthquake risk reduction program. The Act's aims include improved understanding, characterization, and prediction of hazards and vulnerabilities; improved model building codes and land use practices; reduced risks from earthquakes through post-earthquake investigations and education; development and improvement of design and construction techniques; improved mitigation capacity; and accelerated application of research results. On 16 November 1990, President Bush approved Public Law 101-614, "The National Earthquake Hazards Reduction Program Reauthorization Act" which significantly amended the 1977 Earthquake Hazards Reduction Act, refining the descriptions of Agency responsibilities, program goals, and objectives.

As established by the 1977 Act, NEHRP is directly responsible for and has promoted real gains in our understanding and characterization of earthquake hazards, our preparation for earthquakes, and how to mitigate the damage they cause. Much has been accomplished by the NEHRP agencies working both individually, together in cooperative alliances, and with other federal and state agencies, private companies, universities, and regional, voluntary and professional organizations. The program has supported research on:

- Science of earthquakes;
- Earthquake performance of buildings and other structures;
- Earthquake-resistant structural design standards and practices;
- Societal impacts;
- Emergency response and recovery;
- Regional land use Planning; and
- Education programs for the public.

Contributions from these joint efforts have addressed fundamental questions such as: Where have earthquakes occurred in the past?, Where do they occur now?, Where will they likely occur in the future?, What causes earthquakes to occur in a geographic region?, With what frequency do they recur?, How severe are the physical effects of ground shaking and ground failure expected to be in future earthquakes?, How do buildings and lifelines (such as telecommunications lines, transportation, water, sewage, electric power, gas, and liquid fuel lines) perform in the impacted communities?, and How can individuals and communities be better prepared for future earthquakes?

Los Angeles Emergency Preparedness pays off with Northridge Earthquake

Investments in preparedness by the City of Los Angeles, the California Governor's Office of Emergency Services, the California Seismic Safety Commission, the Southern California Earthquake Preparedness Project (SCEPP), the Southern California Earthquake Center (SCEC), NEHRP, and other southern California cities, and private and public emergency response professionals helped reduce the losses that could have occurred from the 1994 Northridge earthquake. NEHRP-supported activities include FEMA's funding of the California Governor's Office of Emergency Services, NEHRP support of the SCEPP, establishment of the National Center for Earthquake Engineering Research (NCEER) with funding by NSF, and most recently the establishment of the Southern California Earthquake Center (SCEC) with funding by NSF and USGS. Efforts of the NCEER, SCEPP and SCEC staff and their outreach programs in raising public awareness of earthquake hazards in the Los Angeles area contributed to better preparedness and an increased attention on the very real earthquake risk faced by citizens of southern California. These actions in turn contributed to a more prompt emergency response and organization in reaction to the Northridge earthquake than might otherwise have happened.

Education and Training Programs

Accomplishments of NEHRP-supported activities also include educating and training experts in earthquake engineering and earth sciences. These experts have provided technical leadership that is recognized worldwide. The Earthquake Engineering Research Institute works to transmit the latest technical information into useful and comprehensible information for various audiences that have a role to play in reducing earthquake losses. The Seismic Safety Commission, Office of Emergency Services, and *Sunset Magazine*, utilizing materials prepared in part through NEHRP-supported activities, have prepared materials for home owners, buyers, and sellers that will enable them to take steps to make their homes less vulnerable to earthquakes. Development of social science knowledge through NEHRP-supported activities has also served as the basis for major improvements in risk communication and education efforts, and will serve as the vehicle for future growth in mitigation activities. In California, for example, the Governor's Office of Emergency Services relies heavily on social science knowledge to advance its risk communication efforts.

NEHRP-Developed Design and Construction Practices and Guidelines

NEHRP contributions have provided:

- Recommended design practices for the seismic safety of new buildings which serve either as a primary source document or as a basis for all three national model building codes and are available for adoption by state and local regulatory jurisdictions;
- Guidelines for assessment and engineering techniques for strengthening of seismically hazardous existing buildings; and
- Contributions to technologies for the seismic safety of lifelines.

It is very difficult to estimate losses that do not occur, but an indication of NEHRP's contributions to loss reduction is the low casualty and property loss rate experienced in U.S. cities during earthquakes of comparable size to earthquakes that caused catastrophic losses in foreign locales. For example, two recent U.S. earthquakes in the magnitude range of 6.7 to 7.2 -- Loma Prieta (1989) and Northridge (1994) -- occurred in or near major population areas and caused relatively

low casualty losses (fewer than 70 people in each case). The social and economic disruption caused by these events was far less than that experienced in recent earthquakes in many other societies, though it is difficult to compare earthquakes in one cultural and geological setting with those in another.

Major factors in these damage differences are the seismic design and construction practices in the United States, the development of preparedness planning efforts, and increased public awareness. In general, buildings and other structures that had been designed and rehabilitated using information traceable to NEHRP efforts performed well during both the Loma Prieta and the Northridge earthquakes. In addition, emergency response organizations helped to minimize social and economic disruption in these cities. The information provided by NEHRP agencies prior to the event contributed to that effective performance.

As a result of NEHRP and collaborative state and local government and private sector efforts, proven, up-to-date seismic design and construction practices for new and existing buildings are available for risk reduction in all areas of the nation. Many communities are now adopting and enforcing mitigation and preparedness measures along with emergency response measures such as preplanning for recovery from an earthquake disaster.

The Nation's Model Building Codes reflect NEHRP Recommendations

All three national model building codes in the United States incorporate seismic risk criteria based on ground shaking hazard maps prepared through NEHRP agency efforts. The Building Officials and Code Administrators International, Inc. (BOCA), National Building Code, and the Standard Building Code include codified text of the *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings* prepared by the Building Seismic Safety Council. Executive Order (E.O.) 12699 Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction (Appendix D1) requires design requirements which improve the seismic safety of new federal buildings. It also provides an incentive to state and local governments to adopt and enforce adequate seismic provisions for new buildings so that new federal buildings can be constructed in their jurisdictions in accordance with E.O. 12699. Executive Order (E.O.) 12941, Seismic Safety of Existing Federally Owned or Leased Buildings, (Appendix D2) signed 1 December 1994, specifies evaluation, and if necessary, mitigation requirements which will improve the seismic safety of existing federal buildings. It requires the adoption and application by federal agencies of the *Standards of Seismic Safety for Existing Federally Owned or Leased Buildings*. It also requires agencies to inventory their owned and leased buildings and to estimate the costs of mitigating unacceptable seismic risks in these structures within four years. The order also requires FEMA to provide Congress with a report on how to achieve an adequate level of seismic safety in federally owned and leased buildings in an economically feasible manner within six years.

Appendix A2. NEHRP Challenges

Although NEHRP has had many successes, it also faces many challenges. In the earth sciences, significant advances have been made in understanding earthquake generation and identifying high risk areas, but developing a means of predicting or even forecasting earthquakes has proved to be a much greater challenge than anticipated. In engineering, while great strides have been made in developing building practices and advocating mitigation practices, the implementation of the practices remains voluntary and thus generally very limited.

The Federal government's earthquake risk reduction efforts, carried out primarily under NEHRP, are generally limited to activities and programs that involve the Federal government. Many important earthquake risk reduction measures, such as those that entail land use and building codes, are entirely within the jurisdiction of state and local governments. The way the member agencies' already mature and focused resources were brought together to create NEHRP may have set the tone for an interagency effort which is well coordinated but not well integrated. Although the language in the 1977 Act included a requirement that NEHRP develop mitigation incentives, none of the agencies have addressed this highly controversial, potentially politically charged, subject as thoroughly as intended.

- The NEHRP program should tie seismic mitigation incentives to all federal financing programs available to state and local governments. The program should include: (1) expanding Executive Order 12699 for new construction to include both direct and indirect federal financing; (2) incorporating mitigation into federal rehabilitation financing programs; (3) linking receipt of federal disaster assistance to mitigation actions; and (4) identifying appropriate incentives to stimulate mitigation actions, particularly for the built environment.

- The NEHRP program needs to capitalize on the large number of federal government programs that support construction and grants by requiring that seismic safety be incorporated into these programs. Further, greater coordination is needed between the NEHRP and non-NEHRP federal agencies in their research and deployment efforts.

- Most state and local governments are unlikely to launch significant efforts to improve mitigation in the absence of stronger federal requirements, guidance, and incentives.

- A high priority need is to develop guidelines for earthquake resistant construction of lifeline facilities, particularly water, gas, and electrical transmission and distribution lines.

- There is a critical need to develop performance-based seismic codes for buildings that incorporate provisions for life-safety as well as other design objectives, such as damage control and post-earthquake functionality.

- If cost offsets such as tax credits, insurance premium reductions, and interest-free loans can be created, more stringent codes and retrofit requirements will be much more palatable to owners, and much easier to enact and enforce by regional and local jurisdictions. Financial inducements must also be provided to these jurisdictions to encourage better training and funding for building and building plan inspectors, better education for the construction trades, and resources for better enforcement.

- Local governments must insist on adequate inspection and enforcement of construction regulations and standards. Educational courses should be mandatory to provide building and building plan inspectors with up-to-date knowledge of principles of seismic design. Local governments should provide qualified, properly trained and adequately funded building and building plan inspectors who have adequate resources to carry out their responsibilities.

- Local governments, with assistance from state or federal agencies, utilities, or other organizations, need to develop realistic earthquake scenarios to evaluate the vulnerability of their communities, to test emergency response plans, and to gain insight for recovery plans.

- The federal government needs to maintain flexibility in recovery policy to react to changed conditions and to reflect the need for seismic hazard mitigation. Exact replacement is an unsound public policy. Government

agencies and professional and trade organizations should develop guidelines and standards to guide earthquake repair in a way that provides for a variety of performance levels. Federal procedures for awarding earthquake recovery funds should require that the federal contribution be used to restore the stricken community to a functioning viable community that has improved seismic safety.

TABLE 1. Frequent concerns and recommendations expressed in past reviews of NEHRP: "Improving Earthquake Mitigation," Report to Congress, 1/93; "Report of the Advisory Committee of the National Earthquake Hazards Reduction Program, 1/93; "An Assessment of Selected User Needs and Recommendations for the NEHRP, 3/94 draft; "The Reauthorization of the Earthquake Hazards Reductions Act," Hearings of the House Committee on Science, Space and Technology, September 14, 1993; and "Practical Lessons from the Loma Prieta Earthquake," National Research Council, 1994.) This report does not necessarily endorse or concur with all of these; some concerns are not under NEHRP control.

Since NEHRP was created several reviews and assessments have been conducted of the nation's earthquake risk reduction efforts. Appendix A summarizes several more recent and representative reviews. These reviews have identified fundamental areas of weakness together with a number of recommendations to improve the national program. Table 1 provides an abbreviated summary of the most frequently repeated recommendations, criticisms, challenges, and opportunities expressed by these recent NEHRP reviews.

Funding for Implementation

The amount of funding for the NEHRP agencies has varied during the program's history. In Fiscal Year 1993 (FY 93) NEHRP's $93 million funding was distributed to FEMA (19%), USGS(48%), NSF (31%), and NIST (2%). Almost 80% of this funding is focused on research into earthquake hazards and engineering techniques to reduce earthquake losses.

The advances generated by NEHRP-funded research and development have provided the basis for a wide range of measures (such as improved land use and building practices) which, if fully implemented, would substantially reduce future earthquake losses. Recognition of these emerging capabilities has led earthquake experts, informed public officials, and to some extent the general public to call for a greatly expanded effort in implementation. This demand must be balanced against the cost of an expanded implementation effort in the face of limited resources. Implementation of loss-reduction measures to existing constructed facilities would require several orders of magnitude more funds than are currently being expended by the Federal government. Most mitigation practices must be voluntarily adopted by bodies largely outside the control of the federal government. As a consequence, the degree of national earthquake risk reduction envisioned by many has not been achieved, a conclusion consistently voiced by advisory committees, expert witnesses, and assessment panels over the past several years.

Building Practices

There is a widely held perception that seismic practices for buildings are intended to preserve property and functionality, when the principal purpose of most present building codes is occupant safety by avoiding building collapse or major failure. Earthquake catastrophes resulting in loss of life can generally be avoided for new construction. The cost of seismic safety for protection of life rarely exceeds two percent of the construction cost for well-designed new buildings. The greatest challenge for seismic safety in new building construction is educating the public, government regulators, owners, designers, and builders in seismic safety practices. This accomplished, practices for seismic safety can in many situations be applied at little or no extra cost for design, construction, or operation.

However, new construction changes the entire American building inventory by as little as one percent each year. This means that the potential number of casualties, damaged buildings, and corresponding social/economic disruptions caused by earthquakes is reduced by only a very small percentage each year. Furthermore, the normal time required to research a new idea, move it

through code acceptance and into widespread practice can be more than a decade. Thus, even over several decades, earthquake loss reduction will be modest in much of the United States despite any great breakthroughs which have or may occur in science and engineering--unless greater attention is given to improving the performance of existing buildings and lifelines.

Unfortunately, the cost of retrofitting buildings for seismic safety is commonly more than costs for such measures during new construction. Costs are often of the same order as for functional or cosmetic renovations. A major FEMA-sponsored project is underway to provide a set of technically sound, nationally applicable guidelines for the seismic rehabilitation of buildings that would assist in the development of building codes.

Other Federal Agencies

Substantial funds to improve building safety, and to conduct research on earthquake hazard reduction, are spent by some non-NEHRP federal agencies. Agencies such as the Department of Veterans Affairs, Department of Defense, Department of Energy, Department of Transportation (Federal Highway Administration), Department of Health and Human Services, Department of Housing and Urban Development, and Nuclear Regulatory Commission all engage in substantial independent hazard identification and risk reduction programs for their mission-oriented programs, and the National Aeronautics and Space Administration (NASA) is active in earthquake process research as part of its Mission to Planet Earth. However, the earthquake-related activities of these non-NEHRP agencies lack an integrating mechanism.

Incentives and the Federal Role

What is the appropriate Federal role within the context of the Strategy? The initial NEHRP legislation envisioned the Federal role as that of a provider of information that would lead state and local governments, private concerns, and private citizens to take action in their own self interest. Subsequent amendments to the legislation added the roles of providing stimulation and promotion of risk reduction actions. However the actual level of risk reduction actions such as the adoption of earthquake resistant building codes by local or state governments has not kept pace with expectation for the results of NEHRP. This gap between risk reduction action to date and expectations has led to the recommendation from the Advisory Committee of the National Earthquake Hazard Reduction Program that NEHRP "incorporate a programmatic implementation mechanism that creates strong incentives for the adoption of earthquake risk reduction measures..." The Committee recommended consideration of tax credits, federal matching grants, requirements for risk reduction action as a condition for Federal government support, and disaster insurance. These recommendations raise questions about their impact on Federal revenue, Federal expenditures, and the Federal role with respect to the historical, if not the constitutional prerogatives, of state and local government. These issues are complex and require extensive analysis to assure that policies have the intended consequences; their resolution will likely require legislation. Some of these issues are currently being addressed by the Administration and the Congress as they explore feasible policy options for encouraging the adoption and enforcement of building codes the purchase, and adequacy of catastrophic insurance.

Appendix B1. National Earthquake Strategy Working Group

Name	Affiliation	Phone	Fax
Murray Hitzman	OSTP (chair)	(202) 456-6086	(202) 456-6025
Miriam Baltuck	OSTP/NASA (chair through 11/94)	(202) 358-0244	(202) 358-2770
Kevin Murdock	CEA	(202) 395-7352	(202) 395-6853
Riley Chung	DOC/NIST	(301) 975-6062	(301) 869-6275
H. S. Lew	DOC/NIST	(301) 975-6061	(301) 869-6275
Diana Todd	DOC/NIST	(301) 975-5296	(301) 869-6275
Richard Wright	DOC/NIST	(301) 975-5900	(301) 975-4032
Edward Bernard	DOC/NOAA	(206) 526-6800	(206) 526-6815
Charles Gutberlet	DOD/CE	(202) 504-4802	(202) 504-4139
William Roper	DOD/CE	(202) 272-0257	(202) 272-0907
James Wilcoski	DOD/CE	(217) 373-6763	(217) 373-6734
Howard Nickerson	DOD/NAVFAC	(202) 433-8758	(202) 433-8777
James Hill	DOE	(301) 903-4508	(301) 903-8585
Bill Luth	DOE	(301)-903-5829	(301)-903-0271
Robert MacDonald	DOI/BOR	(303) 236-8643	(303) 236-4711
Rich Bernknopf	DOI/USGS	(703) 648-6726	(703) 648-6908
Robert Hamilton	DOI/USGS	(703) 648-6714	(703) 648-6592
Walt Hays	DOI/USGS	(703) 648-6711	(703) 648-6717
Elaine Padovani	DOI/USGS	(703) 648-6638	(703) 648-6717
Don Trilling	DOT	(202) 366-4220	(202) 366-7618
James Cooper	DOT/FHWA	(703) 285-2060	(703) 285-2766
Phillip Yen	DOT/FHWA	(703) 285-2315	(703) 285-2766
Kharaiti LalAbrol	DVA	(202) 233-7379	(202) 233-3478
Kim Fletcher	EPA	(202) 260-4794	(202) 260-7906
Jim Makris	EPA	(202) 260-8600	(202) 260-7906
Brian Cowan	FEMA	(202) 646-2821	(202) 646-2577
Mark Russo	FEMA	(202) 646-2701	(202) 646-2577
Ross Mackay	FEMA	(202) 646-2715	(202) 646-2577
Robert Volland	FEMA	(202) 646-3002	(202) 646-3231
Bruce Hall	GSA	(202) 501-1997	(202) 501-3393
Joseph Corliss	HHS	(301) 443-6621	(301) 443-0084
Frank Young	HHS	(301) 443-1167	(301) 443-5146
Eric Noji	HHS/CDC	(404) 488-7350	(404) 488-7335
Bob Fuller	HUD	(202) 708-4549	(202) 708-5966
Jean Lin	HUD	(202) 708-0574	(202) 619-8360
Lou Walter	NASA	(301) 286-8551	(301) 286-1738
Paul Hamilton	NCS	(703) 692-2106	(703) 746-7184
James Kerr	NCS	(703) 692-0698	(703) 746-7184
Dick Moran	NCS	(703) 692-9268	(703) 557-5012
Jerald H. Munson	NCS	(703) 692-0504	(703) 692-2740
William Anderson	NSF	(703) 306-1362	(703) 306-0291
Stephen Mackwell	NSF	(703) 306-1556	(703) 306-0382
Judith Sunley	NSF	(703) 306 1018	(703) 306-0109
James H. Whitcomb	NSF	(703) 306-1556	(703) 306-0382
Andy Murphy	NRC	(301) 415-6010	(301) 415-5074
Thomas Myers	SI	(202) 287-2143	(202) 287-3018
Sara Cavendish	Treasury	(202) 622-0672	(202) 622-0265
Mozelle Thompson	Treasury	(202) 622-2032	(202) 622-0265
Nathalie Valette-Silver	USAID	(703)-875-1568	(703)-875-1708
Thomas Anderson	CTI		

Appendix P2. National Earthquake Strategy Workshop Participants June 6-8, 1994

Miriam Baltuck, Office of Science and Technology Policy (Workshop Chair)
Kharaiti Lal Abrol, Department of Veterans Affairs
Tyler Alper, Treasury Department
Tom Anderson, RAND Critical Technologies Institute
William Anderson, National Science Foundation
Chris Arnold, Building Systems Development
Robert Bachman, Fluor Daniel, Inc.
Ted Barrett, Department of Commerce
James Beavers, Martin Marietta Energy Systems
Eddie Bernard, NOAA PMEL
Richard Bernknopf, USGS
David Brookshire, University of New Mexico
James Carpenter, Bruce Olson Consulting Engineers
Daniel Chavez, Department of Labor
Paulina Chen, EPA
Riley Chung, NIST
Bruce Clark, Leighton & Associates
Lloyd Cluff, Pacific Gas and Elec. Co.
Hal Cochrane, Colorado State University
James Cooper, FHWA
Joseph Corliss, PHS
Brian Cowan, FEMA
Charles Eadie, City of Watsonville, CA
Ronald Eguchi, EQE Engineering & Design
Richard Elsner, California Governor's Office of Emergency Services
Kim Fletcher, US EPA
Robert Fuller, HUD
John Gambel, FEMA
James Goltz, EQE Engineering & Design
Charles Gutberlet, DoD/CE
William Hakala, NSF
Bruce Hall, GSA
John Hall, California Institute of Technology
Robert Hamilton, USGS
Paul Hamilton, NCS
Tom Hayes, Natl. Flood Insur. Program
Walter Hays, USGS
Roger Head, Dept. of Trans. Public Facilities, Anchorage, AK
Chris Heiser, OMB
Tom Henyey, University of Southern California
James Hill, DOE
M. E. Hynes, US Army Engineer Waterways Experiment Station
Cynthia Ingham, UCLA
James Jirsa, University of Texas
Gerald Jones, Consultant, Kansas City
Thomas Jordan, MIT
James Kerr, NCS
Paul Komor, OTA
Eugene LeComte, Insurance Institute for Property Loss Reduction
George Lee, SUNY
Richard Leonard, David Evans & Associates
H. S. Lew, NIST
Chris Lewis, OMB
Jean Lin, HUD
S. C. Liu, NSF
Rocky Lopes, American Red Cross

William Luth, DOE
Marilyn MacCabe, FEMA
Robert MacDonald, BOR
Ross Machan, FEMA
Stephen Mackwell, NSF
George Mader, Spangle Associates
Michael Mahoney, FEMA
James Makris, US EPA
Peter May, University of Washington
Dennis Mileti, Univ. of Colorado
Jane Molloy, Department of Commerce
Richard Moran, NCS
James Mori, U.S. Geological Survey
Kevin Murdock, NEC/CEA
Andy Murphy, US NRC
Thomas Myers, Smithsonian Institution
Eric Noji, CDC/HHS
Thomas O'Rourke, Cornell University
Elaine Padovani, USGS
Earnest Paylor, NASA
William Prescott, USGS
Lawrence Reaveley, University of Utah
Christopher Rojahn, Applied Technology Council
William Roper, DOD/COE
Claire Rubin, consultant. US EPA
John Rundle, University of Colorado
Mark Russo, FEMA
Craig Schiffries, American Geological Inst.
Buddy Schweig, Center for Earthquake Research Info.
Kelley Scott, US Congress OTA
Ellen Seidman, National Economic Council
Larry Shao, U.S.N.R.C.
David Simpson, Incorporated Research Institutions for Seismology
James Smith, BSSC
Douglas Smits, City of Charleston Public Services Dept.
M. P. Singh, NSF
Carl Stepp, Consultant, Austin, TX
William Stewart, William W. Stewart & Associates
Robert Swain, The Coalition of Prof. & Scientific Associations In Support of NEHRP
Mozelle Thompson, US Treasury
Kathleen Tierney, University of Delaware
Tom Tobin, California Seismic Safety Commission
Don Trilling, DOT
Susan Tubbesing, EERI
Randy Updike, USGS
Robert Volland, FEMA
Louis Walter, NASA/GSFC
Craig Weaver, USGS
Robert Wesson, USGS
James Whitcomb, NSF
James Wilcoski, DOD/CE
David Williams, DOD/CE
Richard Witthop, Port of Los Angeles
Richard Wright, NIST
Phillip Yen, FHWA
Eugene Zeller, City of Long Beach Dept. of Building and Safety
Tom Zimmerman, Illinois Emergency Management Agency

APPENDIX C Goals and Targets of the National Earthquake loss Reduction Program (NEP)

The National Earthquake Strategy Working Group recognized that NEHRP lacked an effective means of coordinating non-NEHRP agencies' earthquake activities, as well as efforts of non-governmental and state and local governmental sectors dealing with earthquakes. A major difficulty in evaluating the success of NEHRP and identifying future priorities has been the lack of specific goals, targets, and products against which performance can be measured or expectations revised. The new strategy establishes specific integrated and coordinated research targets and associated products with timelines for completion. Though these targets will undoubtedly be revised, modified, and supplemented as more is learned about earthquake loss reduction, they provide a framework for measuring progress.

The following sections set forth the primary goals that define the strategy. Each goal has several targets which in some cases could be described as projects, but generally are more broadly based. While the targets are prioritized in order of decreasing importance, the goals are not. For most targets one or more products have been identified. The aim of the strategy is to maintain a focus on these products as the separate supporting projects are developed, conducted, reviewed, and completed so that information and technology transfer meets public expectations on national earthquake loss reduction. Consistent with their mission, the Federal agencies planning allocation of limited earthquake-designated resources will take into account the specific targets and products identified as high priority issues by the user community in both the public and private sectors. The dates suggested for meeting targets or completing products are estimated guidelines, not commitments.

Funds for the attainment of these goals are presumed to be limited to those currently in the budgets of agency programs involved in earthquake research or loss mitigation technology development.

Goal 1: Provide leadership and coordination of federal earthquake research

Targets:

1. Work with the National Science and Technology Council to establish a leadership mechanism to assure implementation of the Strategy. The mechanism shall report every two years to the President and to the Congress on its findings, progress, and recommendations relating to earthquake risk reduction. Leadership mechanisms are needed for both national oversight and day-to-day coordination functions.

2. Integrate federal earthquake-related program planning into the new mechanism over a five year period beginning in Fiscal Year 1996. This shall include a detailed analysis during FY 1996 of agency expenditures and planned expenditures with the objective of identifying any redundancies and redirecting expenditures toward high priority targets.

3. Develop a balanced national prioritized research and mitigation agenda, confirmed or adjusted on a regular basis, incorporating a broad-based assessment of user needs that includes the needs of agencies to support special or unique missions.

4. Facilitate cooperation and leverage across all agencies and groups with programmatic interests in earthquake loss reduction, including, but not limited to federal, state, local, private, voluntary, and public utility agencies and groups.

5. Develop an overall nationwide strategic plan to integrate and coordinate existing but currently separate research and mitigation programs into a unified, needs-driven, goal-oriented program consistent with the National Earthquake Strategy goals.

6. Advocate policies and practices nationwide and recommend legislation as appropriate.

7. Conduct a biennial performance assessment and report of coordination and integration activities under the Program. This report shall include accomplishments towards achieving the goals and recommendations for improving the Strategy. As the Program matures the assessment and report can be conducted at less frequent intervals.

8. Provide a focal point for federal international collaborative programs in research on earthquake loss reduction and in technology transfer for improved earthquake hazard mitigation.

Goal 2: Continue to expand technology transfer and outreach

Targets:

1. Develop credible earthquake scenarios including vulnerabilities and loss estimates which are sensitive to economic and political issues, using GIS technology.

Products:

- Planning and Technical Assistance Guide for Emergency Risk Managers and insurance companies, containing scenarios and estimates of loss applicable to specific earthquake-prone regions.
- By the year 2000, publish credible planning earthquake scenarios for representative cities in the eastern and western United States exposed to the highest earthquake hazards.
- Produce and distribute non-technical pamphlets on "Managing Earthquakes in My Town" tailored to the hazard risk of the area of distribution.
- Produce and distribute handbook on proper application of land use planning to reduce risk from seismic hazard.
- Support prototype efforts in appropriate land use.
- Develop response modeling techniques that account for human interactions with the built environment and the behavior of non-structural systems that may contribute to human death or injury or losses of property and functionality.
- Develop model approaches and other recommendations for improving emergency preparedness, recovery and reconstruction planning including topics of earthquake casualties, economic losses, and disruptions to communication, transportation, medical, pubic health, and other critical systems, and human responses to these problems.
- Issue reliable and comprehensive estimates of future losses due to earthquakes and models to make direct comparisons of impacts between regions of the nation.

2. Develop assessments of the costs and benefits of various mitigation strategies for new and existing construction.

Products:

- Handbook to assist facility and community planning groups to understand and estimate their own risk exposure, and realistically estimate mitigation costs and retrofit disruption impacts. Address alternative mitigation and preparedness strategies.
- Engineering criteria handbook for retrofit/rehabilitation of existing facilities.
- Seismic Program Planning Guide with information on property value increase and insurance premium decrease (as provided by the insurance industry) available to support the cost of: 1) studies and planning, 2) non-structural seismic safety hazard mitigation, and 3) retrofitting/rehabilitation of buildings.

3. Targeted training and education programs.

Products:

- Develop, with university instructors, materials suitable for inclusion in building design, architecture, and engineering courses.
- Mass media training seminars and "users manual".
- K-12 grade school teaching modules focusing on the science and technology of seismic mitigation.
- "Training in the work place" curriculum materials.
- Post-earthquake response plans that will provide to federal, state, and local public officials, private industry, and the public information on the cause and effects of earthquakes, the potential for continuing hazard, and the means to recover from the event in the first hours, days, and weeks after an earthquake.
- Newspaper inserts.
- Traveling museum exhibits.
- National Engineers Week teaching module.
- Training programs for design professionals on new hazard mitigation methods.

4. Encourage and assist regional consortia.

Products:

- Training exercises to strengthen federal, state, and local partnerships.
- Support and expand the audience for existing training programs.

5. Embrace and support voluntary mitigation.

6. Communicate achievements, progress, and successes of the National Earthquake loss reduction Program and its member agencies and alliances

Products:

- Short, simple, non-technical summaries of knowledge.
- Newsletters in hard copy and electronic mail.
- CD-Roms with extensive cross-referencing to all earthquake-related work.

7. Encourage and assist the insurance industry through publishing regular reports and presenting updates in information and methodology at insurance industry fora.

8. Develop and disseminate tools for design professionals that incorporate state-of-the-art information on mitigation strategies and methods.

Products:

- Technical briefs on earth science issues written for design professionals (e.g. how to interpret liquefaction potential maps).
- Guidelines on specific aspects of design (e.g. pushover analyses).
- Computer software for improved design of construction.

Goal 3: Improve engineering of the built environment

Targets:

1. Develop improved analytical techniques for dynamic, non-linear response of complex, unconventional materials, structures, and lifelines.

Products:

- Numerical methods, computer software, and modeling procedures to simulate three-dimensional elastic response, inelastic response of basic structure, and soil structure interaction.
- Experimental verifications under laboratory and field conditions of basic seismic behavior of structures and their protective systems.

- Composite materials and hybrid systems consisting of new and existing materials, particularly high-performance materials.
- Dam/reservoir systems including three-dimensional dam-fluid-foundation interactions and sediment effects.

2. Develop new and innovative systems of construction that are economical yet inherently earthquake resistant.

Products:

- Active, passive, and hybrid control technologies.
- System designed semi-rigid frames and braced frames.
- Improved design methods for high-strength concrete structures, steel structures, composite and hybrid structures.

3. Develop performance-based[1] design concepts and criteria for buildings and lifeline systems.

Products:

- Universal damage indices for different types of constructions and engineering systems.
- Damage indices versus earthquake intensity, frequency content, and duration studies for different constructions.
- Probabilistic measures of failure.
- Performance-damage index statistics, studies to develop earthquake parameters and damage-cost relationships for different types of construction, and cost-benefit studies in a probabilistic framework to develop performance-based guidelines for the western, central, and eastern United States.

4. Understand seismic behavior of non-building structures and lifeline systems.

Products:

- Dynamic earthquake behavior of network systems of bridges, other transportation arteries and nodes, power, water, sewage, and communications systems.
- Earthquake countermeasures including development of on-line inspection, monitoring, and control capability, and optimal network management techniques.
- Systems-integrated institutional effectiveness and productivity assessment methodologies to determine infrastructure system losses due to social/economic impediments.

5. Develop effective and economical methods to evaluate and retrofit existing seismically hazardous structures.

Products:

- Performance criteria and engineering design manuals for retrofit measures.
- Advanced technologies for infrastructure health condition assessment and monitoring.
- Analysis of economic issues related to decisions to retrofit, leave in present condition, or demolish structures, and the selection of retrofit techniques.
- Investigation of architectural/functional issues.
- Effective methods of prioritizing retrofit efforts regionally and by structural type considering potential hazard, limitations of economic resources, and social demand and impact.

6. Develop experimental engineering research capability and conduct verification and proof-of-principle projects.

Products:

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[1] Performance-based design criteria go beyond the intent of extant codes by incorporating a combination of more stringent practices in hazard definition, design analysis, test, construction, and inspection specifically tailored to ensure a specified level of structure damage control and contents functionality for a defined earthquake threat.

- Comprehensive examination of long-term experimental earthquake engineering research needs and corresponding requirements for technical manpower, testing facilities, and financial resources.
- Detailed investigation and qualification of earthquake-resistant design concepts and viability of protective systems.
- Upgrade existing experimental facilities and establish new facilities as needed and allowed by budgetary constraints.

Goal 4: Improve data for construction standards and codes

Targets:

1. Develop and make available for use by code writing bodies, state insurance offices, and insurance firms resource documents on improved, functionality-preserving seismic design criteria for new buildings and other structures, including cost estimates.

Products:

By the year 1998 -

- Provide guidance on earthquake risk reduction to federally supported day care centers and schools in moderate to very high earthquake hazard areas.
- Provide guidance on earthquake risk reduction to all hospitals and medical care facilities in moderate to very high earthquake hazard areas.
- Provide a catalog of risk reduction activities to private insurance companies.

By the year 2000 -

- Develop performance-based design criteria for new buildings and other structures, including non-structural systems and requirements for functionality of essential buildings, and implement the criteria in national standards and model building codes and the practices of federal agencies.
- Develop consistent, prescriptive criteria for small new buildings, including criteria for non-structural systems, and implement the criteria in national standards and model building codes and the practices of federal agencies.
- Develop prescriptive model earthquake building code requirements.
- Develop and implement programs which educate state and local government officials, designers, builders, and building officials towards code adoption and implementation.
- Suggest implementation incentives (permits, financing, insurance, resale) which account for social context.
- Provide consensus-based information, in non-technical terms, on regional seismic risk affecting 41 States and U.S. Territories.

2. Develop and make available resource documents for use by code writing bodies, insurance companies, and regulators on performance-based seismic design standards for lifelines.

Products:

- By the year 1997, prepare and deliver guidance packages on mitigation grants and case studies of mitigation products to 30% of school districts in moderate to very high earthquake hazard areas.
- By the year 1998, provide guidelines for the seismic safety of new and existing lifelines.
- By the year 2000, propose national standards for functionality-preserving seismic design of new lifeline construction.
- By the year 2000, conduct 20 workshops for building investors and developers in moderate to very high earthquake hazard areas.
- By the year 2003, propose national standards for seismic evaluation and retrofit of existing lifeline infrastructure.

3. By the year 2005, develop and make available resource documents for use by code writing bodies, insurance companies, and regulators on rehabilitation standards for existing buildings and other structures.

Products:

- By the year 1996, develop and conduct courses on seismic design, engineering, and siting for architectural and engineering faculty.
- By the year 1996, develop teaching modules on earthquake science and mitigation technology for K-12 grades and provide teacher enhancement workshops to encourage integration of modules in existing K-12 curricula.
- By the year 2000, establish earthquake safety education programs in all federal agencies in moderate to very high earthquake hazard areas.
- By the year 2000, develop technologies for assessing the condition of existing buildings, cost-effective strengthening techniques, and rational guidelines for the assessment and strengthening of populations of potentially hazardous existing buildings.
- By the year 2005, implement the above technologies through national standards and model building codes.
- Support building retrofit/rehabilitation demonstration projects.
- Identify, collect and publish a compendium of existing design guides.
- Field test the compendium of design guides in demonstration projects.

4. By the year 2000, introduce multi-hazard standards.

Products:

- Basic prescriptive wind, earthquake, and tsunami model building practice requirements.
- Education towards code adoption.
- Training of designers and contractors.
- Collaborate with the insurance industry on multi-hazard rating and loss modeling.

5. Develop improved capabilities for analysis and testing of structures, including lifelines.

Products:

- Detailed study, such as the shake table study, comparing options requested for completion in FY 95.
- Structural response modeling techniques that account for nonlinear and inelastic behavior of buildings and structures, and active and passive control systems to increase resistance to structural collapse.
- Capabilities to predict the dynamic and inelastic response of a specific structure (for all types of buildings and lifelines) to a specific, free field ground motion with consideration of soil-foundation-structure interaction, and damping and hysteretic energy absorption for inelastic structural response.
- Proof-testing capability to test products.

6. Develop means to mitigate tsunami effects by incorporating readings from deep-water pressure sensors to improve early tsunami warning systems.

Goal 5: Continue development of seismic hazards and risk assessment tools

Targets:

1. Improve loss estimation methodology. Develop earthquake scenarios linking building types and lifelines with the effects of strong shaking and ground failure to provide better estimates of life losses, injury, public health impact, property losses, and indirect economic effects.

Products:

- Identification of, and predicted seismic intensities for, areas vulnerable to site amplification of strong ground motion.
- Hazard maps suitable for planning and engineering in critical urban and suburban areas vulnerable to site amplification liquefaction and landslides.
- Predictive models for liquefaction-induced ground deformation and effects on building foundations, lifelines, and waterfront properties.
- Standards of practice for hazard analysis and mitigation of ground failures.
- Standards for the management of shelters for people with special needs, such as people evacuated from hospitals or nursing homes.

2. By the year 1998, develop seismic risk assessment methodology and quantify seismic risk for communities exposed to high seismic hazard.

Products:

- Inventories and database of information on buildings and lifelines at risk.
- Quantitative loading models accounting for bedrock ground shaking, site effects, duration of shaking and interactions of the structure with supporting soils and rock.
- New techniques for seismic microzonation that will ultimately take into account potential losses of the built environment and will influence policies and practices.

3. By the year 2000, provide demonstration seismic hazard microzonation maps for representative sections of selected cities exposed to the highest earthquake hazard.

Products:

- First maps for trial use and comment by the year 1998
- Digital surficial and bedrock geology maps for major urban areas at risk from earthquakes showing areas of potential ground failure (liquefaction, landslides, lateral spreads, and others).

4. By the year 2005, provide regional seismic hazard maps, interpretations, and guidelines as the basis for seismic zonation, implementation of earthquake codes, and local land-use decisions.

Products:

- Characterize the earthquake potential (including the magnitude, frequency and effects of future earthquakes) of the United States on a regional and national basis to a precision of at least 200 km.
- Identify active faults, define their geometry, and determine the characteristics and dates of past earthquakes.
- Predict strong ground shaking and ground failure, including subsidence, landslides, and liquefaction.
- Predict regional earthquake losses due to identified earthquake hazards through the use of modern statistical methodologies.
- Identify zones of earth movement in the eastern United States where active faults are not present at the surface.
- Conduct a series of workshops across the country in order to assimilate, incorporate, and share more than a decade of federal, academic, and private sector research into the estimates of seismic source zones.

5. Improve earthquake hazard assessment and forecasting using historical seismicity and paleoseismicity, and evaluate the role of emerging technologies such as Global Positioning System (GPS), Synthetic Aperture Radar (SAR) differential interferometry, high performance seismometers, borehole strainmeters, and monitoring of microseismicity and hydrologic effects at depth.

Products:

- Develop and evaluate methods for short- and intermediate-term earthquake forecasts and apply the methodologies to selected regions with high earthquake potential.

- Determine the accumulation of crustal strain in a GPS network grid of sufficient density in earthquake-prone regions to evaluate whether these data allow estimates of short- to moderate-term earthquake potential (complete grid deployment by 1999).
- Integrate synthetic aperture radar (SAR) data on small crustal movements for earthquake sequences in southern California with satellite and aircraft radar data to complement the continuous observations available from GPS and seismic arrays (begin systematic aircraft SAR measurements in 1996).
- Deploy and operate an expanded network of permanently-placed GPS receivers and develop the necessary regional centers for data analysis, supplementing receivers with complementary installation of boreholes at select sites.
- Develop and evaluate methods for long-term forecasting using historical seismicity and paleoseismicity.
- Monitor microseismicity and hydrologic phenomena such as well water levels to characterize crustal strain at depth.

6. Provide high-quality earthquake recordings and derived basic seismic information to researchers and practitioners on an ongoing basis.

Products:

- Complete planned modernization of the U.S. earthquake recording capability by completing development of the National Seismic Network stations by the year 2000.
- Upgrade seismic networks to include broad-band, digital stations augmented with three component strong-motion sensors.
- Establish near-real time recording standards for the National Seismic Network.
- Complete the Global Seismic Network and IRIS data center.
- Update and expand national strong-motion network to digitally record ground motion and structural response in urban zones of highest risk.

7. Understand critical earthquake topics such as plate interactions in subduction zones, blind faults, and fold and thrust belts appropriate to such geographically diverse areas as the Pacific Northwest, mid-continent, and Eastern United States.

Products:

- Models of fault system dynamics and interactions for specific regions at risk.
- Synthetic seismograms for strong ground motion and space/time histories.
- Geologic studies of exhumed faults, geophysical surveys to remotely determine fault zone properties, scientific drilling for sampling and in-situ properties determination, laboratory rock mechanics experiments, and induced-seismicity studies.
- Quantitative models of the physics of the earthquake process, including generic physical models of the earthquake cycle, methods relating seismic waveforms and fault slip, wave propagation effects, and general features of rupture.
- Testing forecasting/prediction methodologies using ideas from the sciences of chaos and complexity, including neural networks and non-linear time series prediction.

8. Improve understanding of strong ground motions, including nonlinear site response, directivity and topographic effects, and foundation instability.

Products:

- Conduct research on recorded motion and publish results in a format understandable to design professionals.
- Develop site-specific ground motion models for engineering design.
- Develop techniques for engineering assessment of liquefaction effects, soil-structure interaction, landslide and foundation subsidence.

9. Provide an accessible digital GIS database.

Products:

- By the year 2000, acquire and make accessible over the INTERNET the digital topographic maps needed to cover major urban areas with the highest seismic risks.
- By the year 2005, make accessible over the INTERNET a catalog of existing earthquake hazard- and risk-related GIS data sets, including data sets from local and state agencies, and a list of the types of information most needed in digital form by various users, including building code writers and insurance companies.

10. Improve foreknowledge of and response to tsunami hazards.

Products:

- By the year 2000, acquire and make accessible over the INTERNET the digital topographic maps needed to cover major urban areas with the highest seismic risks.
- Provide demonstration inundation maps for tsunami-threatened coastal towns (pattern after hurricane surge inundation maps in use over the past 30 years for the east and Gulf of Mexico coastal area) using GIS technology.
- Link offshore wave measurements to tsunami warning systems to provide a near-real time warning capability to coastal systems.
- Identify evacuation procedures and routes and warning systems.
- Provide demonstration all-hazard maps (tsunamis, flooding, and geologic) using GIS format for select sites along the west coast.

Goal 6: **Analyze seismic hazard mitigation incentives**

Targets:

1. Evaluate mechanisms and advise Congress and relevant Executive Branch Offices to achieve adoption and enforcement by the year 2000 of up-to-date model building codes and standards to govern all new building and lifeline design and construction.

2. Provide guidance and lead by example on specific mitigation measures which may be used in a federal incentive program.

Products:

- Provide text to extend Executive Order 12699 to include "indirectly" financed federally assisted construction projects.
- Provide guidance for developing a community rating system for seismic hazards.

3. Better understand the socioeconomic barriers to mitigation and preparedness.

Products:

- Identify risk mitigation measures associated with insurance coverage for workers compensation, fire, professional errors and omissions, general liability, and other lines that account for most of the expected insured losses.
- Foster the practice of professional peer review (not plan checking) for design of new and retrofit/rehabilitation of existing important, unique, essential, and critical facilities.
- Establish national standards for professional competence in relevant professions (geology, engineering, construction, emergency response).

3. Investigate barriers to insurance premium restructuring.

Products:

- Identify insurance regulatory reforms to reduce barriers.

Goal 7: Develop understanding of the societal and institutional issues related to earthquake hazard reduction

Targets:

1. Determine the social and economic benefits and costs of various mitigation measures such as codes, land-use planning, insurance, and educational programs for different sectors of society.

Products:

- Knowledge base for model mitigation and preparedness programs in at-risk regions of the country.
- Recommendations for the most effective mix of mitigation strategies.
- Hazard reduction factors that can be translated into insurance premium discounts.

2. Identify the social, economic, and political factors that facilitate and hinder the adoption and implementation of seismic safety measures.

Products:

- Information on the characteristics of populations exposed to earthquake hazards and the differences among the various social groups and institutional sectors in their vulnerability.
- Information on risk perception and its impact on mitigation and preparedness actions.
- Recommendations for improving the effectiveness of hazard information and dissemination efforts.
- Knowledge on the effectiveness of incentives and regulations in furthering mitigation and preparedness actions.

3. Investigate the societal responses to earthquakes, including emergency response systems, and individual, business, and community recovery from such events.

Products:

- Information on the acquisition, communication, and utilization of risk and damage information.
- Assessments of the effectiveness of existing mitigation and preparedness mechanisms and identification of alternative approaches.
- Guidelines on ways in which the reconstruction period can be used by decision makers to reduce future vulnerability.

4. Analyze multi-hazard mitigation and preparedness planning.

Products:

- Comparisons of responses to earthquakes and other hazards and disasters.
- Techniques for integrating seismic safety planning into a community's general planning efforts.
- Basis for transferring policies which have proved successful in reducing other natural hazard risks to the earthquake context.
- Techniques for integrating seismic safety planning and other hazards into a multi-hazard community planning approach.

Goal 8: Analyze the medical and public health consequences of earthquakes

Targets:

1. Identify potential strategies to prevent or mitigate the adverse public health consequences of earthquakes through epidemiological research.

2. Integrate casualty and medical needs predictions into earthquake loss estimates.

Products:

- Realistic models for estimating casualties and medical requirements.
- Realistic scenarios for pre-earthquake preparedness simulations, and exercises.

3. Develop validated indicators for rapid assessment of the health effects and potential health effects of earthquakes and related health needs in order to determine the most appropriate medical requirements during the critical first few hours after impact.

4. Develop more effective rescue, medical training, and public health programs.

5. Review effective operational procedures for meeting the health needs of people with special requirements such as evacuees from hospitals and nursing homes.

6. Develop an emergency communications system to ensure effective coordination of medical and health needs at the local, State, and federal levels.

Goal 9: Continue documentation of earthquakes and their effects

Targets:

1. Establish standards and specifications for official documentation of earthquakes by 1996.

2. Prepare and publish a reconnaissance report, collect ephemeral data, and complete major aspects of a research plan within one year of each major earthquake event.

3. Prepare and publish an in-depth report within four years of each major earthquake event.

4. Post information on electronic data base for easy access by any interested party.

Appendix D1. Text of Executive Order 12699 of January 5, 1990
Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction

By the authority vested in me as President by the Constitution and laws of the United States of America, and in furtherance of the Earthquake Hazards Reduction Act of 1977, as amended (42 U.S.C. 7701 et seq.), which requires that Federal preparedness and mitigation activities are to include "development and promulgation of specifications, building standards, design criteria, and construction practices to achieve appropriate earthquake resistance for new ...structures, and an examination of alternative provisions and requirements for reducing earthquake hazards through Federal and federally financed construction, loans, loan guarantees, and licenses..." (42 U.S.C. 7704 [f][3,4]), it is hereby ordered as follows:

Section 1. Requirements for Earthquake Safety of New Federal Buildings.

The purposes of these requirements are to reduce risks to the lives of occupants of buildings owned by the Federal Government and to persons who would be affected by the failures of Federal buildings in earthquakes, to improve the capability of essential Federal buildings to function during or after an earthquake, and to reduce earthquake losses of public buildings, all in a cost-effective manner. A building means any structure, fully or partially enclosed, used or intended for sheltering persons or property.

Each Federal agency responsible for the design and construction of each new Federal building shall ensure that the building is designed and constructed in accord with appropriate seismic design and construction standards. This requirement pertains to all building projects for which development of detailed plans and specifications is initiated subsequent to the issuance of the order. Seismic design and construction standards shall be adopted for agency use in accord with sections 3(a) and 4(a) of this order.

Sec. 2. Federally Leased, Assisted, or Regulated Buildings.

The purposes of these requirements are to reduce risks to the lives of occupants of buildings leased for Federal uses or purchased or constructed with Federal assistance, to reduce risks to the lives of persons who would be affected by earthquake failures of federally assisted or regulated buildings, and to protect public investments, all in a cost-effective manner. The provisions of this order shall apply to all the new construction activities specified in the subsections below.

(a) Space Leased for Federal Occupancy. Each Federal agency responsible for the construction and lease of a new building for Federal use shall ensure that the building is designed and constructed in accord with appropriate seismic design and construction standards. This requirement pertains to all leased building projects for which the agreement covering development of detailed plans and specifications is effected subsequent to the issuance of this order. Local building codes shall be used in design and construction by those concerned with such activities in accord with section 3(a) and 3(c) of this order and augmented when necessary to achieve appropriate seismic design and construction standards.

(b) Federal Domestic Assistance Programs. Each Federal agency assisting in the financing, through Federal grants or loans, or guaranteeing the financing, through loan or mortgage insurance programs, of newly constructed buildings shall plan, and shall initiate no later than 3 years subsequent to the issuance of this order, measures consistent with section 3(a) of this order, to assure appropriate consideration of seismic safety.

(c) Federally Regulated Buildings. Each Federal agency with generic responsibility for regulating the structural safety of buildings shall plan to require use of appropriate seismic design and construction standards for new buildings within the agency's purview. Implementation of the plan shall be initiated no later than 3 years subsequent to the issuance of this order.

Sec. 3. Concurrent Requirements. (a) In accord with Office of Management and Budget Circular A-1 19 of January 17, 1980, entitled "Federal Participation in the Development and Use of Voluntary Standards," nationally recognized private sector standards and practices shall be used for the purposes identified in section 1 and 2 above unless the responsible agency finds that none is available that meets its requirements. The actions ordered herein shall consider the seismic hazards in various areas of the country to be as shown in the most recent edition of the American National Standards Institute Standards A58, Minimum Design Loads for Buildings and Other Structures, or subsequent maps adopted for Federal use in accord with this order. Local building codes determined by the responsible agency or by the Interagency Committee for Seismic Safety in Construction to provide adequately for seismic safety, or special seismic standards and practices required by unique agency mission needs, may be used.

(b) All orders, regulations, circulars, or other directives issued, and all other actions taken prior to the date of this order that meet the requirements of this order, are hereby confirmed and ratified and shall be deemed to have been issued under this order.

(c) Federal agencies that are as of this date requiring seismic safety levels that are higher than those imposed by this order in their assigned new building construction programs shall continue to maintain in force such levels.

(d) Nothing in this order shall apply to assistance provided for emergency work essential to save lives and protect property and public health and safety, performed pursuant to Sections 402, 403, 502, and 503 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) (42 U.S.C. 5170a 5170b, 5192, and 5193), or for temporary housing assistance programs and individual and family grants performed pursuant to Sections 408 and 411 of the Stafford Act (42 U.S.C. 5174 and 5178). However, this order shall apply to other provisions of the Stafford Act after a presidentially declared major disaster or emergency when assistance actions involve new construction or total replacement of a building. Grantees and subgrantees shall be encouraged to adopt the standards established in section 3(a) of this order for use when the construction does not involve Federal funding as well as when Federal Emergency Management Agency (FEMA) funding applies.

Sec. 4. Agency Responsibilities. (a) The Director of the Federal Emergency Management Agency shall be responsible for reporting to the President on the execution of this order and providing support for the secretariat of the Interagency Committee on Seismic Safety in Construction (ICSSC). The ICSSC, using consensus procedures, shall be responsible to FEMA for the recommendation for adoption of cost-effective seismic design and construction standards and practices required by sections 1 and 2 of this order. Participation in ICSSC shall be open to all agencies with programs affected by this order.

(b) To the extent permitted by law, each agency shall issue or amend existing regulations or procedures to comply with this order within 3 years of its issuance and plan for their implementation through the usual budget process. Thereafter, each agency shall review, within a period not to exceed 3 years, its regulations or procedures to assess the need to incorporate new or revised standards and practices.

Sec. 5. Reporting. The Federal Emergency Management Agency shall request, from each agency affected by this order, information on the status of its procedures, progress in its implementation

plan, and the impact of this order on its operations. The FEMA shall include an assessment of the execution of this order in its annual report to the Congress on the National Earthquake Hazards Reduction Program.

Sect. 6. Judicial Review. Nothing in this order is intended to create any right or benefit, substantive or procedural, enforceable at law by a party against the United States, its agencies, its officers, or any person.

/s/ George Bush

The White House,
January 5, 1990

Appendix D2. Text of Executive Order 12941 of December 1, 1994
Seismic Safety of Existing Federally Owned or Leased Buildings

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in furtherance of the Earthquake Hazards Reduction Act of 1977, as amended by Public Law 101-614, which requires the President to adopt "standards for assessing and enhancing the seismic safety of existing buildings constructed for or leased by the Federal Government which were designed and constructed without adequate seismic design and construction standards" [42 U.S.C. 7705b(a)], it is hereby ordered as follows:

Section 1. Adoption of Minimum Standards. The Standards of Seismic Safety for Existing Federally Owned or Leased Buildings (Standards), developed, issued, and maintained by the Interagency Committee on Seismic Safety in Construction (ICSSC), are hereby adopted as the minimum level acceptable for use by Federal Departments and agencies in assessing the seismic safety of their owned and leased buildings and in mitigating unacceptable seismic risks in those buildings. The Standards shall be applied, at a minimum, to those buildings identified in the Standards as requiring evaluation and, if necessary, mitigation. Evaluations and mitigations that were completed prior to the date of this order under agency programs that were based on the Standards deemed adequate and appropriate by the individual agency need not be reconsidered unless otherwise stipulated by the Standards.

For the purposes of this order, buildings are defined as any structure, fully or partially enclosed, located within the United States as defined in the Earthquake Hazards Reduction Act of 1977, as amended, [42 U.S.C. 7703(5)], used or intended for sheltering persons or property, except for exclusions specified in the Standards.

Section 2. Estimating Costs of Mitigation. Each agency that owns or leases buildings for Federal use shall, within 4 years of the issuance of this order, develop an inventory of their owned and leased buildings and shall estimate the costs of mitigating unacceptable seismic risks in those buildings. The cost estimate shall be based on the exemptions and evaluation and mitigation requirements in the Standards. Guidance for the development of the inventory and cost estimates will be issued by the ICSSC no later than 1 year after the signing of this order. Cost estimates with supporting documentation shall be submitted to the Director of the Federal Emergency Management Agency (FEMA) no later than 4 years after the signing of this order.

Section 3. Implementation Responsibilities. (a) The Federal Emergency Management Agency is responsible for (1) notifying all Federal departments and agencies of the existence and content of this order, (2) preparing for Congress, in consultation with the ICSSC, no later than 6 years after the issuance of this order, a comprehensive report on how to achieve an adequate level of seismic safety in federally owned and leased buildings in an economically feasible manner, and (3) preparing for the Congress on a biennial basis, a report on the execution of this order.

(b) The National Institute of Standards and Technology is responsible for providing technical assistance to the Federal Departments and agencies in implementation of this order.

(c) Federal departments and agencies may request an exception of this order from the Director of the Office of Management.

Section 4. Updating Programs. The ICSSC shall update the Standards at least every 5 years. It shall also update the Standards within 2 years of the publication of the first edition of FEMA's Guidelines for Seismic Rehabilitation of Buildings and Commentary.

Section 5. Judicial Review. Nothing in this order is intended any right to administrative or judicial law, or any other right, benefit, or trust responsibility, substantive or procedural, enforceable by law against any party against the United States, it's agencies or intrumentalities, its officers or employees, or any person.

/s/ William J. Clinton

The White House,
December 1, 1994

Abbreviation/Acronym List

BOCA	Building Officials and Code Administrators International, Inc.
BOR	Department of Interior Bureau of Reclamation
BSSC	Building Seismic Safety Council
CEA	Council of Economic Advisors
CDC	Centers for Disease Control and Prevention
CE	Corps of Engineers
CSSC	California Seismic Safety Commission
CTI	Critical Technologies Institute
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOT	Department of Transportation
DVA	Department of Veterans Affairs
EERI	Earthquake Engineering Research Institute
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographic Information System
GPS	Global Positioning System
GSA	General Services Administration
GSFC	Goddard Space Flight Center
HUD	Department of Housing and Urban Development
HHS	Department of Health and Human Services
ICSSC	(Federal) Interagency Committee on Seismic Safety in Construction
IDNDR	International Decade for Natural Disaster Reduction
IRIS	Incorporated Research Institutions for Seismology
NASA	National Aeronautics and Space Administration
NAVFAC	Navy Facilities Command
NCEER	National Center for Earthquake Engineering Research
NCS	National Communications Service
NEC	National Economic Council
NEHRP	National Earthquake Hazards Reduction Program
NEP	National Earthquake loss reduction Program
NESW	National Earthquake Strategy Working Group
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSTC	National Science and Technology Council
NRC	Nuclear Regulatory Commission
OES	Office of Emergency Services (California)
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
OTA	Congressional Office of Technology Assessment
PMEL	Pacific Marine Environmental Laboratories
SAR	Synthetic Aperture Radar
SCEC	Southern California Earthquake Center
SCEPP	Southern California Earthquake Preparedness Project
SI	Smithsonian Institution
USAID	United States Agency for International Development
UJNR	United States - Japan Cooperative Program on Natural Resources
USGS	United States Geological Survey

Strategy for National Earthquake Loss Reduction

EXECUTIVE SUMMARY

It is likely that one or more severely damaging earthquakes will strike the United States within the next decade. As the 1994 Northridge earthquake showed, the cost of earthquake damage to buildings and infrastructure is unacceptably high. The 1995 Kobe, Japan earthquake provided a stark reminder that earthquakes can be killers, even in countries that have undertaken substantial earthquake mitigation. But while earthquakes are inevitable natural hazards, they need not be inevitable disasters. Our nation can reduce the losses of life, casualties, property losses, and social and economic disruptions from future earthquakes through prudent actions.

Congress recognized this in 1977 with the passage of the Earthquake Hazards Reduction Act which established the interagency National Earthquake Hazards Reduction Program (NEHRP). NEHRP has been successful in conducting research to increase knowledge about earthquake hazards and on engineering techniques to reduce earthquake loss. However, risk reduction actions based on research results, such as the adoption of earthquake resistant building codes by state and local governments, have not kept pace with expectations.

The new National Earthquake loss reduction Program (NEP) is designed to strengthen and extend NEHRP*. The NEP aims to focus scarce research and development dollars on the most effective means for saving lives and property and limiting the social disruptions from earthquakes, coordinate federal earthquake mitigation research and development and emergency planning in a number of additional agencies beyond those in NEHRP to avoid duplication and ensure focus on priority goals, and cooperate with the private sector and with state and local jurisdictions to apply effective mitigation strategies and measures. It goals are:

- Provide leadership and coordination for federal earthquake research;
- Improve knowledge of earthquake processes and effects;
- Continue to expand technology transfer and outreach;
- Improve engineering of the built environment;
- Improve data for construction standards and codes;
- Continue the development of seismic hazards and risk assessment tools;
- Analyze seismic hazard mitigation incentives;
- Develop understanding of societal impacts and responses related to earthquake hazard mitigation;
- Analyze the medical and public health consequences of earthquakes; and
- Continue documentation of earthquakes and their effects.

Leadership and coordination of the NEP will be conducted by the Federal Emergency Management Agency (FEMA). Coordination through FEMA will ensure both increased attention to transfer of research results to the user community and that the research remains focused on goals that can aid mitigation and save lives and property. The NEP is budget neutral. No redirection of budgetary authority between Federal agencies is implied or intended. The non-Federal implementation of earthquake loss mitigation practices is not a direct fiscal responsibility of the NEP. However, because most mitigation decisions are made at the state or local levels of government, or in the private sector, the ultimate success of the NEP largely depends on its effectiveness in stimulating the actions of these groups to mitigate earthquake risks.

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* The program was designed under the direction of the Office of Science and Technology Policy (OSTP) by the National Earthquake Strategy Working Group (NESW) which included representatives of over twenty federal agencies that have a program interest in earthquake loss reduction. Recognizing that implementation of earthquake loss mitigation occurs primarily at the state and local level, the NESW held a national forum with engineers, scientists, architects, building officials, social scientists, and emergency managers from state and local government, academia, and the private sector to gain their views, concerns, and recommendations which are reflected in this report.

ABSTRACT

It is likely that one or more severely damaging earthquakes will strike the United States within the next decade. But while earthquakes are inevitable natural hazards, they need not be inevitable disasters. Our nation can reduce the losses of life, casualties, property losses, and social and economic disruptions from future earthquakes through prudent actions. Congress recognized this in 1977 with the passage of the Earthquake Hazards Reduction Act which established the interagency National Earthquake Hazards Reduction Program (NEHRP). NEHRP has been successful in conducting research to increase knowledge about earthquake hazards and on engineering techniques to reduce earthquake loss. The new National Earthquake loss reduction Program (NEP) is designed to strengthen and extend NEHRP. The NEP aims to focus scarce research and development dollars on the most effective means for saving lives and property and limiting the social disruptions from earthquakes, coordinate federal earthquake mitigation research and development and emergency planning in a number of additional agencies beyond those in NEHRP to avoid duplication and ensure focus on priority goals, and cooperate with the private sector and with state and local jurisdictions to apply effective mitigation strategies and measures. Leadership and coordination of the NEP will be conducted by the Federal Emergency Management Agency (FEMA). Coordination through FEMA will ensure both increased attention to transfer of research results to the user community and that the research remains focused on goals that can aid mitigation and save lives and property. The NEP is budget neutral. No redirection of budgetary authority between Federal agencies is implied or intended. The non-Federal implementation of earthquake loss mitigation practices is not a direct fiscal responsibility of the NEP. However, because most mitigation decisions are made at the state or local levels of government, or in the private sector, the ultimate success of the NEP largely depends on its effectiveness in stimulating the actions of these groups to mitigate earthquake risks.

For Additional Copies, Contact:

Robert Volland, Mitigation Directorate, FEMA
telephone: (202)646-2767
fax: (202)646-4387
http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/html/NSTC_Home.html

For Further Information, Contact:

Environment Division, OSTP
telephone: (202)456-6202
fax: (202)456-6025

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